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Lateralisation of infant holding by mothers: A longitudinal evaluation of variations over the first twelve weeks.

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Lateralisation of infant holding by mothers: A longitudinal evaluation of variations over the first twelve weeks.

The maternal preference to hold infants on the left rather than right side of the body was examined longitudinally, with attention to four explanations: maternal monitoring of infant state, maternal handedness, infant proximity to the mother's heartbeat, and preferred infant head position. The side and site of holding were measured over the first twelve weeks of the lives of 24 infants. Information about group and individual consistency in holding side allowed novel evaluation of the theories. A strong bias to hold on the left dropped below significance when the infants were aged twelve weeks and was limited to specific holding positions. Findings were generally consistent with the monitoring hypothesis, and little support was found for the three alternative explanations.

Key Words: Infancy, Cradling bias, Infant Holding, Laterality, Emotional processing

LATERALISATION OF INFANT HOLDING BY MOTHERS: A LONGITUDINAL
EVALUATION OF VARIATIONS OVER THE FIRST TWELVE WEEKS.

Parenting behaviour has critical relevance for the survival of individuals and the species and the bias women show to hold their babies on the left rather than right side of the body (e.g. de Chateau, Holmberg & Winberg, 1978; Salk, 1960) may play an important role in supporting infant survival and development. A theoretically compelling explanation of the bias relates to maternal monitoring of infant state, incorporating the role of hemispheric specialisation of attention and emotional processing (e.g., Manning & Chamberlain, 1990). However, further empirical investigation is required to distinguish this from competing explanations involving simpler associations between holding side and maternal handedness, proximity to maternal heartbeat, and infant head position. By measuring consistency in group and individual holding preferences over time and across multiple trials, this longitudinal assessment of mothers' holding preferences offers detailed analyses which shed light on theoretical perspectives which prevail in this field.

Between 75% and 85% of right-handed women preferentially hold infants on the left side of their bodies and the same lateral bias, albeit weaker, is found in left-handed women (e.g., De Chateau et al., 1978; Salk, 1960) and in fathers (Scola & Vauclair, 2010a). The bias appears to be universal; it has been found in the USA (e.g., Dagenbach, Harris & FitzGerald, 1988; Salk, 1960), South Africa (Saling & Cooke, 1984), Europe (e.g., De Chateau et al., 1978) and Japan (Negayama, Kawai, Yamamoto, Tomiwa, & Sakakihari, 2010). Dolls also

elicit a left holding bias in nulliparous women (e.g., Saling & Tyson, 1981) and even young girls (Saling & Bonert, 1983; Todd, 1998). However, a left bias was not found when other objects are held (Harris, Cárdenas, Spradlin, & Almerigi, 2010; Todd, 2001), leading to an assumption that it is stimulated by baby-like characteristics; the effect is sufficiently strong that it is elicited by imagining holding a baby (Harris, Almerigi, & Kirsch, 2000; Nakamichi & Takeda, 1995).

Maternal monitoring of infant state

Successful parenting requires awareness of internal as well as external signals of risk to infant viability, including hunger, airway obstruction, pain, and changes in temperature or muscle tone. Monitoring of infant state is said to be advantaged by holding on the left as information originating from that side is transferred to the mother's right hemisphere which is specialised for attention (Whitehead, 1991) and emotional processing (Bourne, 2010). Effective monitoring is pertinent to all primates and may be selected for early in our evolutionary history; a left bias for holding infants has been found in non-human primates (Hopkins, Bard, Jones, & Bales, 1993; Manning, Heaton, & Chamberlain, 1994), who also have a degree of hemispheric specialisation (Hopkins, 2007; Hopkins, Taglialatela, Leavens, Russell, & Schapiro, 2010). Indeed, evidence of a right hemisphere bias for processing the social-emotional behaviour of proximal others, manifesting as a left visual field preference, is found in a number of animal species, including marine mammals and non-human primates (Karenina, et al., 2013; MacNeilage, Lesley & Vallortigara, 2009; Queresmini, Forrester, Spiezio & Vallortigara, 2014).

The maternal monitoring explanation is compatible with evidence of a reduction in the left cradling bias in depressed women (Reissland, Hopkins, Helms & Williams, 2009; Weatherill et al., 2004) who show decreased levels of sustained attention (Weatherill et al., 2004). Similarly, when mothers are stressed, attentional resources may be diverted from the infant; even temporary experience of stress has been found to reduce the tendency to hold a doll on the left (Suter, Huggenberger & Schachinger, 2007).

Infant monitoring involves a range of modalities, and at least three – auditory, visual, and tactile – deserve consideration. The evidence linking left holding to lateral asymmetries in auditory processing is at present somewhat tenuous; no clear association between left ear advantage in auditory processing and maternal left-holding has been found (Donnot & Vauclair, 2007). Indeed, infant sounds are generally available bilaterally, and distinctive links between left-holding and auditory processing cannot be predicted with great confidence.

In contrast, a link between left holding and left visual field advantage in the perception of face stimuli has been found in studies using dolls (Bourne & Todd, 2004; Huggenberger, Suter, Reijnen, & Schachinger, 2009; Vauclair & Donnot, 2005) though no equivalent right visual field advantage appears to be associated with right holding (Bourne & Todd, 2004; Harris et al., 2010). However, when mothers held infants, no correlation between visual field advantage and holding side was found (Donnot & Vauclair, 2007; Vauclair & Scola, 2009; Scola & Vauclair, 2010b). To pursue this theory further, it must be established whether infants who are held on the left side are also in positions where their face is visible to the holder.

It should also be noted that cradling on the right might have implications for the baby's subsequent cognitive development; right-holding in infancy may result in reduced exposure to high quality emotional information about faces. In one study, infants of mothers with a left cradling preference demonstrated a typical left visual field (right hemisphere) bias

for faces on chimeric face tests, whereas infants of mothers with a right-holding bias lacked a visual field bias (Vervloed, Hendriks, & van den Eijnde, 2011).

As well as the visual modality, touch is a powerful form of communication, with skin to skin contact providing information on infant muscle tone, skin humidity and temperature. Right hemisphere brain mechanisms, analogous to those for auditory and visuo-spatial systems, process tactile information (Coghill, Gilron, & Iadarola, 2001). Evidence of touch as an evolutionarily old mechanism for processing socio-emotional information is indicated by a left-side bias for touching in dolphins, which may arise from a preference for using the left eye when making tactile contact with conspecifics (Sakai, Hishii, Takeda and Kohshima (2006). However, there is conflicting information about the degree of skin sensitivity on the left and right sides of the human body (see Harris, 2010) and much of the research relates to the hands touching inanimate stimuli. Despite Whiting's (1981) contention that Western infants rarely have skin to skin contact, mothers are often seen to touch infants' heads, hands and feet with their own hands and faces. Preferential processing of tactile information in the right hemisphere and/or greater skin sensitivity on the mother's left side requires that babies are held in positions where skin contact can be comfortably achieved. Although no difference was found in the tactile sensitivity of the left and right breast (Kaplan-Solms & Saling, 1988) this test was not specific to touching infants and no analysis of touching infants with the face has been made.

Regardless of the modalities involved, explanations implicating maternal monitoring need to account for developmental change. A reduction in the intensity of infant monitoring would be expected with maturation (cf. Horne's (2010) discussion of the 'developmental window of vulnerability'). In addition, communicative exchanges are likely to diversify as mothers begin to direct their infant's interest towards surrounding stimuli and adopt the

preferred 'en face' position for communication, typically after the age of three months (Kaye, 1982).

Mothers do not just passively monitor babies but also actively regulate infant state. Holding on the left is typically associated with soothing the infant and characterised by maternal speech at a lower pitch and amplitude than that associated with right holding, which is linked to initiating or maintaining infant arousal (Reissland, 2000). It is necessary, therefore, to take variability in the context of holding into account when interpreting the evidence.

Alternative explanations of the left holding bias

Explanations which compete with the monitoring hypothesis include those relating to the functionality of handedness, the availability of the mother's heart sounds and accommodation to infant head posture. Each, individually, gives rise to specific expectations which distinguish them from the maternal monitoring hypothesis.

Handedness. Holding a baby in the left arm typically frees the holder's dominant hand for other tasks so handedness is seen as the most 'obvious' explanation (e.g., van der Meer & Husby, 2006). Evidence for this explanation is weak; though van der Meer and Husby (2006) find a relationship between doll-holding side and handedness this is in the context of a bi-manual task and so findings cannot be generalised to a simple holding situation. When participants hold a baby without additional demands, the predicted complementary patterns of behaviour of right- and left-handed people are not found. Whilst Donnot (2007) found a left-bias in left-handed students holding dolls, no equivalent bias was found for left-handed mothers holding infants. Similarly, Scola and Vauclair (2010b) found no lateral bias in a study of 29 left-handed mothers holding newborn infants. Nevertheless,

the basic 'handedness' hypothesis is compelling, at least with respect to right-handed women, and predicts a high degree of consistency in individuals across time which remains to be established. Moreover, explanations pertaining to hand preference and maternal monitoring of infant state are not mutually exclusive and both may be considered markers of cerebral dominance; for example, the incidence of atypical (right-hemisphere) dominance for language is found to increase linearly with the degree of left-handedness, from 4% in strong right-handers to 27% in strong left-handers (Knecht et al., 2000). **Heartbeat sounds.** One of the earliest and most attractive explanations of the left-side bias is that mothers hold their babies close to their hearts, because heartbeat sounds, imprinted pre-natally, have a soothing effect (Salk, 1960). A direct test of the 'heartbeat hypothesis' is problematic but a fragment of evidence comes from Todd and Butterworth (1998), who tested the cradling preference of a mother with the rare condition of situs inversus with dextrocardia. Although her heart is situated on the right side of her body in the mirror-image of the normal position, this right-handed mother held her five-week-old infant on the left in all twelve trials of a procedure similar to the one reported here. Todd and Butterworth (1998) also found no evidence that babies aged between 4-5 weeks old were positioned where the heart sounds are loudest. The heartbeat hypothesis predicts consistency but it is likely that its effect would be limited to early infancy. To provide evidence for this theory, it is necessary to determine whether mothers prefer to hold newborn infants where heart sounds are audible at least in the first weeks of life.

Infant head position. Another possibility is that mothers accommodate their behaviour to infants' own lateral biases in head posture. The majority of newborn infants (65 - 80%) preferentially position their heads facing to the right of the body midline when lying supine (e.g. Michel, 1961; Turkewitz, Gordon & Birch, 1965) and this preference typically

persists until 2 months with subsequent decline, disappearing by around 12 weeks in full-term infants (Piek, Gasson, Barret & Case, 2002). The left holding bias may be adaptive in early infancy by avoiding obstruction to the infant's mouth and nostrils and later by maximising maternal access to infant facial signals and enhancing face to face interaction. Although each explanation depends on left holds, the first relates to upright holds (against the shoulder or neck) whilst the others pertain to an infant lying supine on the arm or held facing the mother.

Maternal left holding rates fit with infant head position rates relatively well and some support for this hypothesis was found in experiments where a doll's head position was manipulated (Bundy, 1979; Todd, 1998). However, no clear relationship between infant head position and holding side has been found (Dagenbach et al., 1988; Scola & Vauclair, 2010b; Thompson & Smart, 1993). Variation in measures of infant head position and time and context of testing may account for different findings (Rönnqvist & Hopkins, 1998). There is also some doubt about the consistency of head position in individual infants (Barnes, Cornwell, Fitzgerald & Harris, 1985) and it is possible that mothers respond to the infant's immediate, rather than preferential, head position. In sum, the head position hypothesis predicts a left holding bias at specific sites on the mother's body and that maternal and infant preferences complement one another.

The current study

The current study was designed to provide a detailed data set for consultation in relation to specific hypotheses arising from different explanations of the left holding bias. Methodological features included continuous observation over time (more typical of non-human primate research) rather than 'snapshot' measures and detailed information about the position at which the infant was held in relation to the mother's body.

Observation across twelve sequential trials, conducted at four times during the infants' first four months of life, allowed an assessment of the relative magnitude of the cradling bias over time and tested individual consistency in lateral holding preferences, a factor which is critical to some theoretical approaches but which typically remains unanalysed. Mothers were not required to engage in any other task except holding their baby and systematic observations assessed the relationship between holding position and the style of mother-infant interaction.

The 'maternal monitoring' theory gives rise to the expectation of a reduction in the left-cradling bias over time, because the need for vigilant monitoring of infant state will diminish as infant motor and respiratory systems mature. Monitoring in the visual modality predicts a left bias only when the infant's face or head is within the mother's visual field, that is, held upright facing the mother or cradled in her arms. Correspondingly, a theory involving a left side advantage in tactile monitoring requires that the infant is accessible to touches with the left side of the mother's body and this would be most easily achieved when the infant is held upright on the left side.

In contrast, no age-related reduction in the left holding bias or individual variation in holding side is predicted by the handedness hypothesis. However, if heart sounds are only salient for newborns, an initial tendency to hold the infant in a position with access to the maternal heartbeat (in contact with her trunk at the midline or left side) would decrease after the first weeks of life. Finally, an explanation involving preferred head position would predict a reduced cradling bias after 6-8 weeks and variability and fluctuation dependent on the infant head position in a given trial.

METHOD

Participants

Twenty-four primiparous women, aged between 26 and 41 years ($M = 31$ years, $SD = 3.97$) and their healthy full-term infants (11 girls and 13 boys), aged between one day and 13 weeks, participated. Only primiparous mothers were included to minimise any effect of previous experience in caring for infants. Mothers were recruited in pregnancy via the midwifery services in Brighton, U.K. All mothers were white British, living in the South East of England and of middle to high socio-economic status.

Main procedure

Participants were seen four times in their own homes: the mean age at first visit was 4.19 days (SD 1.52 days) for vaginal and 6.63 days (SD .52 days) for Caesarean deliveries. Subsequently, visits were made when the infant was 4-5, 8-9 and 12-13 weeks old.

The infant was placed supine, on a mat, with the head away from the mother who sat on a chair at a distance of 400 cm. She was asked to pick up and carry the baby back to the chair and to sit holding him/her in any way that she felt comfortable. After 30s she was asked to replace the baby on the mat. The whole procedure was repeated twelve times at intervals of 10s. Babies were tested when they were quietly or actively awake and the procedure was terminated if infants became distressed; therefore there was consistency in infant state within and between trials and between infant participants. All procedures were filmed and at least 20% of material was subject to inter-rater reliability analysis.

After the final visit, mothers completed Annett's (1970) Hand Preference Questionnaire and asked which eye they would use to look through a telescope and which foot they would use to kick a ball.

Infants' spontaneous head position: Additional procedure

Because, the right-head-turning preference is strongest in the early weeks of life, a continuous record of spontaneous head position was made at the first two visits, prior to the

cradling observations. A camera was positioned behind the infant's head as they lay supine on a mat when awake but calm. Parents were requested to kneel behind the infant and hold his/her head at the midline for 30s before gently releasing it, without applying any lateral pressure, and moving to a position where they would not be visible to the infant. Filming continued for between 220 and 300s, being terminated if the infant became distressed and scores were expressed as a proportion of the total recording time. Data were unavailable for three babies who fell asleep (1) or cried (2).

Coding categories

Holding position

Holding side was determined by the position of the midline of the infant's head in relation to the midline of the mother's body: a) to the left; b) to the right; or c) midline. The site at which the infant was held on the mother's body was also recorded. The precise duration of holds at different sites and sides was coded electronically.

When the infant was held on the same side of the mother's body for the majority of that trial the side of holding was recorded as '*Left*' or '*Right*', accordingly. The majority of the trial was deemed to be the duration of 25 seconds (83%) or more of the 30 second trial. Where infants were held on the same side of the mother's body for less than 83% of the trial, holding side was categorised as '*Change*'. Note that for our main analysis of left-holding bias, the majority of trial time was used to categorise holding on each trial because the distribution of left-holding was essentially categorical on most occasions; however, requiring a full 30 seconds on the same side was deemed inappropriate because mothers frequently changed side of holding for very short durations of time as they initially settled their babies into their arms or prepared to put them down.

Mothers were observed to hold their infants in one of two site categories, Upright and Cradled, as defined below:

Upright. Held in the hands or arms with the central line of the head positioned at or less than 45 degrees from the midline of the mother's body. Subcategories include:

- 1) Upright Facing. Held in the hands or arms, away from the mothers' body, in face to face orientation.
- 2) Upright Inward. Held against the mothers' body in ventral/ventral contact, against the shoulder or trunk facing either away from or towards the midline of the mother's trunk (face not easily visible to mother).
- 3) Upright Outward. Held against the trunk or 'seated' on the lap in a dorsal/ventral position, facing away from the mother (face not easily visible to mother).

Cradled. Held supine in the mother's arm/s with the midline of the head more than 45 degrees from the midline of the mother's body (face easily visible to mother).

Inter-observer agreement was reasonable for duration of holding at each side and site (r s ranged between .65 and .76) and infant head position ($r = .62$).

Coding specific to the 'heartbeat hypothesis' (Visit 1 only)

As the heartbeat hypothesis applies most strongly to newborns, holding positions providing differential access to the sound of the mother's heart beat were classified according to the baby's head position at the first visit only.

Trunk. Head was in contact with the mother's upper trunk and ears below her shoulder line (Left, Right and Midline)

Shoulder. Ears were at or above the mother's shoulder line (Left and Right).

Holding away. Head not in contact with the mother's upper trunk (e.g., baby sitting or lying on the mother's lap or held outstretched; (Left, Right and Midline).

Inter-observer agreement on the duration of holding at each side and site was good (r s ranged between .75 and .89).

Touch

A record was made of whether the mother touched the baby with her left or right cheek. Inter-observer agreement was excellent ($k = .98$).

Coding of infant head position

Spontaneous head position (Visit 1 and 2 only). A measurement scale, marked on film, was superimposed over the monitor screen to allow for accurate scoring. Scoring began when the infants' head was released from the midline and the duration of holding to the left, right, and midline was measured to a maximum of 300s. Inter-observer agreement was good ($r = .83$). Two scoring methods were used to classify head position as left or right, based on descriptions of Rönqvist and Hopkins (1998). The 'specific' method defined a lateral position as the head being turned more than 5° from the midline (0°), whereas the 'global' method required the head to be turned 30° or more from the midline.

Within-experiment infant head position. At each trial of each visit, infant head position was noted twice: 1) when the mother began her approach, and 2) when the mother first touched the infant to pick him/her up. As the two measures were identical on 94.43% of all the trials, only the second was used in analyses. Head position was scored as either left or right when it was estimated to be more than 5 degrees from the midline. Reliability on scores of infant head position ($k = .69$) and maternal holding side ($k = .84$) was also good. Coding head position when the infant was held was unreliable and so this behaviour was not included in analysis.

RESULTS

Left holding bias

One-sample t-tests tested whether the proportion of trials where mothers held on the left for more than 25s of the 30s total duration was significantly greater than 0.5. A clear left holding bias was found at the first three Visits but this dropped below significance at Visit 4: Visit 1, M proportion = .69, SD .34, $t_{23} = 3.98$, $p = .01$; Visit 2, M proportion = .79, SD .27, $t_{22} = 6.02$, $p = .001$; Visit 3, M proportion = .72, SD .30, $t_{23} = 2.78$, $p = .002$; Visit 4, M proportion = .59, SD .34, $t_{23} = 1.41$, *ns*. A one-way ANOVA on these mean proportions, with Visit as the within-subjects variable, showed a significant main effect of Visit, $F(3,21) = 3.440$, $p = .035$, and Reverse Helmert contrasts showed that left holding at Visits 1 to 3 was significantly higher than at the last visit ($p = .014$), with no significant contrasts among the former.

Of the 24 mothers, 18 (75%) held their babies on the left side for more than 50% of trials; eleven (45%) held on the left for 80% or more of trials at three or more of the four visits. The corresponding percentages for right holding were 4.17% (1 mother) and 0%. Six mothers showed inconsistent lateral preferences: five (20.83%) ranged between left holding for less than 20% of trials at one visit to more than 80% left at another. Only one (right-handed) mother showed no clear bias to the left or right at any visit; the mean proportion of trials when she held the infant on the left ranged between 40% and 70% across the four visits.

The Handedness Explanation

There was no indication that the three left-handed mothers behaved differently from the majority. Only one of the six mothers who held on the left for less than 50% of the trials was left-handed and she was not the most consistent right holder. When scores on Annett's (1970) handedness questionnaire were correlated with the mean duration of holding the infant on the left, no significant associations were found at any visit (Visit 1, $r = -.17$; Visit 2, $r = -.28$; Visit 3, $r = .02$; Visit 4, $r = .02$, all $ps > .1$).

Although footedness is said to be a better indicator of emotional lateralisation than handedness (Elias, Bryden & Bulman-Fleming, 1998) there was no indication of its influence on holding position; mean proportion of left holding on lateral trials for four left-footed mothers = .65 (SD = .23) and = .70 (SD = .25) for right-footed mothers. Additionally, there was no evidence that eye dominance predicts left-holding; mean proportion of left holding on lateral trials for five mothers reporting a left eye preference = .73 (SD = .26) and = .69 (SD = .24) for mothers with a right eye preference.

The Heartbeat Explanation

Although mothers showed a left bias when holding newborns and they were held at the trunk for almost half of the time (see Table 1), a detailed analysis showed no particular advantage to the pericardial area of the left trunk and so failed to support the ‘heartbeat’ explanation. A two-way ANOVA with Side (Left vs. Right) and Site (Trunk vs. Shoulder vs. Away) as the within-subjects variables showed a main effect of Side, $F(1,23) = 4.41, p < .05$ but a main effect of Site, $F(1,23) = 10.92, p < .0001$, emerged only because Shoulder holds were chosen less frequently than the other positions. There was no interaction between side and site of holding, $F < 1$.

Insert Table 1 here

The Infant Head Position Explanation

Twelve (57.14%) of the 21 infants for whom data were available at both of the first two visits showed a consistent head turning preference (scored by the Specific method) over the first two visits; eight (66.67%) held their heads to the right and four (33.33%) to the left for more than half of the duration of both tests (i.e., 150 seconds or more).

If the left holding bias is driven by the infant’s habitual head turning preference, it would be expected that infants would be held on the side contra-lateral to their preferred head turning position as measured in the pre-trial test. The correlation between the mean duration

of holding the infant at each side over the 12 trials and the mean duration for which their head was turned in the opposite direction was calculated according to both the ‘Global’ ($> 30^\circ$ from midline) and ‘Specific’ ($> 5^\circ$ from midline) scoring methods. No significant relationship between either left holding and right head position or right holding and left head position was found in either case at either visit (r s between $-.33$ and $.11$, ns).

When infants were first picked up by the mothers, one-sample t -tests (with the test value set at 0.5) on the mean proportion of trials at each visit in which the infant was held on the opposite side of the mother’s body to the direction in which his/her head faced showed that this proportion never exceeded 0.5 . Mean proportions at the four visits were $.39$, $.42$, $.47$, and $.33$, all ns apart from the final visit, $p = .03$, when the relationship was in the opposite direction to that predicted. Further analyses confirmed that this pattern held for particular sites of holding, specifically Cradling and Upright Inward.

The Maternal Monitoring Explanation

Holding Site

In order to evaluate the theory that the left holding bias facilitates maternal monitoring of infant state, the duration of holding at each site was measured; separate ANOVAs of the duration of holding at the ‘left’ and ‘non-left’, with Side and Visit as within-subjects variables, were conducted for each holding site. Figure 1 shows the mean duration of holding at each of the four sites, subdivided by the side of holding.

Insert Figure 1 here

Cradled site. An overall left side bias was found when babies were cradled in a position where their faces would be easily visible to their mothers, $F_{1,22} = 8.46$, $p < .01$, and cradling also varied by infant age, $F(1,22) = 26.69$, $p < .001$. An interaction between Side and Visit approached significance, $F(1,22) = 2.55$, $p = .06$, and a significant linear trend on this

interaction showed that the Cradled site was adopted more frequently when infants were aged less than one week and reduced between the first and the last visit, $F(1,22) = 4.56, p < .05$.

Upright Inward. At this position, when infants' heads were easily accessible to maternal touch, the left bias approached significance, $F(1,22) = 3.74, p = .07$, and a significant quadratic trend on the visit variable, $F(1,22) = 5.86, p = .02$, indicated that mothers tended to hold their babies in this position longer at the second and third visits than they did at the first or last. There was a significant interaction between side and visit, $F(1,22) = 5.86, p = .02$, and a significant quadratic trend on this interaction, $F(1,22) = 7.07, p = .01$. One-sample t-tests confirmed that the left bias at this site was significant at Visit 2, $t(22) = 2.98, p = .007$, and approached significance at Visit 3, $t(23) = 2.01, p = .057$.

Touch

Table 2 shows that mothers were likely to touch their babies' heads with the left, rather than right, cheeks and a significant majority did so at the second and third visit (binomial tests: Visit 1, *ns*; Visit 2, $p < .01$; Visit 3, $p < .05$; Visit 4, $p = .06$). This may of course be because the left cheek was more accessible when infants were held on the left.

Insert Table 2 here

Upright Facing. This site was chosen relatively infrequently and no main effect of side was found, $F < 1$. However, a significant linear trend indicated that babies were increasingly held in this position as they got older, $F(1,22) = 12.12, p < .002$. Mothers typically held the infant away from the body at or near the midline with clear visual access to the face. The coding of side did not adequately reflect that infants were typically held with the head at or within a few degrees at either side of the midline; this happened in 58 (82%) of a total of 71 instances.

Upright Outward. No main effect of side was found at the Upright Outward site, $F < 1$. However, the effect of visit was highly significant, $F(1,22) = 22.68, p < .001$, and there

was a significant linear trend on this variable, $F(1,22) = 48.18, p < .001$. Babies were very rarely held at this site when they were one week old or less but this site was chosen more frequently for older infants (Visit 1, 2 mothers; Visit 2, 5 mothers; Visit 3, 14 mothers; Visit 4, 22 mothers). The mean duration (in seconds) of episodes of mother-infant conversation at this position also increased over successive visits (Visit 1, $M = 2.74, SD = .47$; Visit 2, $M = 6.46, SD = 7.05$; Visit 3, $M = 9.80, SD = 6.88$; Visit 4, $M = 11.86, SD = 6.87$).

Qualitative observations at different holding sites

Some qualitative observations of mothers' spontaneous behaviour and speech production are included in order to illustrate the changes in communicative interactions between the mother-infant dyads and their relationship to holding patterns.

Cradled (left side bias). Cradling was associated with touching the babies' heads or hands. Mothers spoke to them briefly, quietly and infrequently. Speech typically consisted of soothing remarks and comments on state (e.g., "Is that OK? Are you comfy now? Is that better?").

Upright Inward (left bias approached significance). In this position, infants' faces were not easily visible to the mothers who typically spoke briefly and infrequently and often patted or rubbed the infant's back and touched the head with the hand or cheeks. They made general remarks or commented on infant state (e.g., "There you are, you are a bit grizzly today aren't you?").

Upright Facing (no lateral bias). Holding upright was typically associated with conversation-like exchanges (e.g., "You are so beautiful, aren't you? (Pause) What a beautiful boy! (Pause) You are aren't you?"). The mean duration of exchanges varied between 2.73 and 22.63 seconds and tended to be longer when infants were aged over, rather than under, 8-9 weeks (Visit 1, $M = 6.57, SD = 4.49$; Visit 2, $M = 5.84, SD = 6.1$; Visit 3, $M = 8.63, SD = 4.86$; Visit 4, $M = 9.96, SD = 5.45$).

Upright Outward (no lateral bias). No lateral preference was found at this holding site; the infant was typically shifted from left to right so that he/she faced the object that the mother referred to. Speech typically involved reference to objects or events within the infant's visual field (e.g., "Look, there's Daddy's gloves, he hasn't taken them to work. Silly Daddy, isn't he?").

DISCUSSION

Mothers in this longitudinal study showed an overall bias to hold their infants on the left side, consistent with previous research. This was strongest when babies were aged less than 9 weeks but significant only when they were cradled in the arms. When held upright against the mothers' trunk or shoulder in ventral/ventral contact the left bias approached significance. Although these two sites were chosen most frequently, holding at two other sites was observed (Upright Outward, Upright Facing); however, these were not subject to a lateral bias. The Cradled position was chosen most frequently when infants were aged one week or less; at each subsequent visit, the mean duration of holding at this position reduced, whereas holding at Upright positions increased. These changes in maternal behaviour may support the infant's developing regulation of postural control (Negayama et al., 2010; Prechtl, 1984) and may be associated with different styles of communicative interaction, as exemplified in our qualitative data. Overall, our analyses do not favour explanations of the left bias based purely on maternal handedness, proximity to the maternal heartbeat, or infant head position. We address these explanations first, and consider how their relevance may change with infant age, before turning to the maternal monitoring explanation.

The Handedness Explanation

No relationship between holding side and maternal handedness was apparent at any of the four infant ages tested. The three left-handed participants behaved in similar ways to the majority (it is not known whether the three left-handed mothers in this study have a pattern of hemispheric specialisation consistent with that of most right-handed people, as McManus, 1999 finds in the case for approximately 70% of left handed people). More particularly, the reduction of the left holding bias over time and the presence of within-mother variations in holding side do not support a handedness explanation.

The Maternal Heartbeat Explanation

Specific analyses designed to evaluate the possibility that left holding is related to the maternal heartbeat found that newborn infants were no more likely to be held in positions where the heartbeat was audible to them than where it was not. When placed in context with evidence from other studies which fail to replicate the salience of heart sounds for newborns (see Detterman, 1978), there is scant support for this theory. The analyses specific to the heartbeat explanation were conducted only at the first visit when babies were one week old or less as heartbeat sounds were deemed to be particularly pertinent for the youngest infants. However, the hypothesis is predicated on the assumption that holding the baby in a position to maximise proximity to the heartbeat has adaptive value in soothing the infant. Thus, while the hypothesis clearly cannot be the sole explanation for the left holding bias, it is nonetheless plausible that babies might be held in such a position in specific instances where the mother wants to soothe them.

The Infant Head Position Explanation

Infants aged less than nine weeks tended to hold their heads on the right, rather than left, as consistent with previous studies (e.g. Rönqvist & Hopkins, 1998). However, the bias only attained significance when lateral head turns of up to 30° were measured and infants did not necessarily show a consistent lateral preference over the two tests; only approximately

60% of individuals did so (a similar inconsistency over time was observed by Barnes et al., 1985). Despite a multiplicity of tests, the proposition that infants are held on the mothers' left sides as a general response to infant head position was not supported, either when infants were aged one week or less or when they were four-five weeks old. These findings are consistent with those of Scola and Vauclair (2010b) who found no relationship between holding side and newborn's asymmetrical tonic neck reflex.

The goodness of fit between theoretical explanations at different age points.

Influences on lateral holding preferences may vary as a function of infant age. Although no association between maternal handedness and holding side was found at any of the four time points of this study, such a relationship may be apparent when older infants and children are held and/or when there is a need to keep the dominant hand free for other activities.

In the procedures adopted here, there was no evidence that infants aged one week old or less were held on the left in order to maintain proximity to the sound of the mother's heart. However, this explanation may only apply when mothers aim to soothe distressed infants and this possibility was not tested. Finally, infant head position was considered to be a possible factor in left-holding bias at an early age, yet no relationship was found at either of the first two visits.

The Maternal Monitoring Explanation

Observations of holding side and site – and of the consistency of individual preferences – provide information about the viability of the theories relating to maternal monitoring via the specialised right hemisphere. When babies were cradled in the left arm, mothers' visual access to the face was enhanced; the preference for holding newborns in this position is consistent with the view that visual monitoring is most critical when infants are less mature (Horne, 2010). The fact that the left-side bias was weaker (only approaching statistical significance) when infants were held upright and facing inward towards the

mother's shoulder or trunk is compatible with this explanation, given that the baby's face would be less easily visible. In a similar vein, the absence of any lateral bias in the case of Upright Facing and Upright Outward positions – which became more frequently used as infants increased in age – is reasonable insofar as the focus of the mother-baby interaction seems to be shifting from maternal monitoring to communication. In addition, maternal speech to the infant was consistent with the change of focus from comments on infant state to conversation-like interactions.

Our data indicates a reduction in the left bias as infants mature. An explanation might be that the adaptive value of the bias may be most critical in the early weeks or, alternatively that the driver/s of the bias may change over time. Our finding that the magnitude of the left bias decreased when infants were aged between three and four months, is consistent with findings of lower left-holding rates among older children (e.g., Dagenbach et al., 1988; Negayama et al., 2010; Scola & Vauclair, 2010b; Weatherill et al., 2004). A continuation of longitudinal analysis for our sample of mothers beyond 13 weeks would obviously be helpful for evaluating the trends in left holding, but it should be noted that other research has not identified any significant relationship between lateral holding preference and infant age between 3 and 14 months (Reissland et al., 2009). In sum, the collective body of evidence is compatible with the notion that the left holding bias relates to specific adaptations to support maternal monitoring in the first 9 weeks of an infant's life and we suggest that this involves other modalities besides the visual.

Although the cradled position was chosen most frequently for newborn infants, the tendency to hold the infants aged between four and nine weeks in an Upright Inward position, when a left-side bias was also apparent, may reflect maternal support and monitoring of infant head and general postural control which develop progressively during this period

(Bayley, 1969). Younger babies were rarely held in the Upright Outward or Upright Facing positions where no left bias was apparent.

One direction for further research concerns a particular aspect of sensory processing that may be relevant for maternal monitoring, namely tactile contact. Touch provides useful information for monitoring infant temperature and muscle tone. Aside from the way in which left Cradling and left Upright Inward holds by definition facilitate tactile input on the left side of the body, we also observed a tendency for many of the mothers to touch their babies' heads with their own cheeks, particularly with their left cheeks. One can of course argue that this kind of lateral bias in tactile contact is simply a consequence rather than a cause of the general left holding bias. However, the overall pattern is consistent with some authors' proposition that skin sensitivity is greater on the left side of the body (Weinstein, 1963).

Individual Variation

Observation of the behaviour of individual women across sequential trials and at different time points has provided new data to inform the crucial issue of individual consistency over time. The data suggest that our sample could be divided into three subgroups: 1) 18 of the 24 mothers held left for the majority of all trials across the four visits of the study; 2) one (right-handed) mother showed a clear and consistent right bias; and 3) the remaining five mothers showed considerable variability over time.

Monitoring theories involving hemispheric specialisation in attention and emotional processes can accommodate the finding that a small minority of mothers show right holding preference, since they may exhibit atypical brain organisation. Between two and 10% of right-handed people and 20 to 30% of left-handed people are estimated to have atypical hemispherical specialisation with language in the right-hemisphere (Knecht et al., 2000; McManus, 1999) and this explanation may apply to the consistent right-holder in this study.

Further explanations for inconsistent preferences have also been considered: situational characteristics, mother's mental health, and fluctuating asymmetry. Firstly, Reissland (2000) proposed that holding side preference varies by communicative context. This explanation is entirely consistent with our own data from developmental changes in holding: younger babies were typically spoken to in soothing tones as they were cradled on the left side, whereas the most intense communicative episodes were seen with older infants who were held upright and facing the mother, close to the midline. Similarly, differences in communicative intent could underpin the variations exhibited by the 'inconsistent' mothers in our sample. This explanation closely relates to a second, which centres on maternal mental health. The contingencies of monitoring and communication vary according to mothers' negative affect (e.g. Weinberg & Tronick, 1998), and variations in maternal mental health over the course of the study could have contributed to individual variations across time.

Finally, there may be a more complex association between holding and the degree of hemispheric specialisation of the holder. Manning et al. (1997) found left holding rates correlated with low levels of fluctuating asymmetry, which is said to signify optimal transmission of information to the right hemisphere. If this model were applied to the data from this study, the group of mothers who showed an inconsistent lateral bias would be presumed to have higher levels of fluctuating asymmetry. This kind of variability may go some way towards explaining inconsistencies and discrepancies within the literature regarding associations between infant/doll holding side and measures of hemispheric specialisation (Bourne & Todd, 2004; Donnot & Vauclair, 2007; Harris et al., 2010; Huggenberger et al., 2009; Lucas et al., 1996). It could therefore be informative to compare hemispheric laterality data from participants, especially mothers, who show a consistent lateral cradling preference with those who do not.

Conclusion

The present study builds on the existing literature in evaluating the merits of various proposed hypotheses regarding the origin of mothers' left holding bias. Explanations appealing to the mothers' handedness, to the location of the maternal heartbeat, and to the head position of the infants were clearly not sufficient for interpreting the longitudinal data presented here. The observed pattern of results was, however, largely consistent with explanations that focus on the advantages of left holding for monitoring infant state in the early weeks of life. However, further research is clearly needed to evaluate the links with hemispheric specialisation that underpin this account. Indeed, as discussed above, we should recognise that there is in all likelihood more than one determinant of the lateral holding preferences, each contributing to a greater or lesser extent at different infant ages depending on the situational, social-communicative, and emotional context of the mother-infant interaction.

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Table 1

The mean duration per trial (maximum 30s) when newborn babies were held at each side and site (midline holds excluded)

	Left			Right		
	Trunk	Shoulder	Away	Trunk	Shoulder	Away
Mean	8.70	1.87	8.40	6.06	.06	4.03
(SD)	(9.14)	(3.73)	(7.71)	(7.56)	(.20)	(6.00)

Table 2

Number and percentage of mothers who touched the baby's head at least once with their left and/or right cheeks at each visit

Visit	Left only	Right only	Both	Neither
1 (0-1wk)	6 (25%)	1 (4.17%)	7 (29.17%)	10 (41.67%)
2 (4-5 wk)	11 (47.83%)	1 (4.35%)	6 (26.09%)	5 (21.74%)
3 (8-9 wk)	12 (50%)	3 (12.5%)	3 (12.5%)	6 (25%)
4 (12-13 wk)	7 (29.17%)	3 (12.5%)	7 (29.19%)	7 (29.17%)

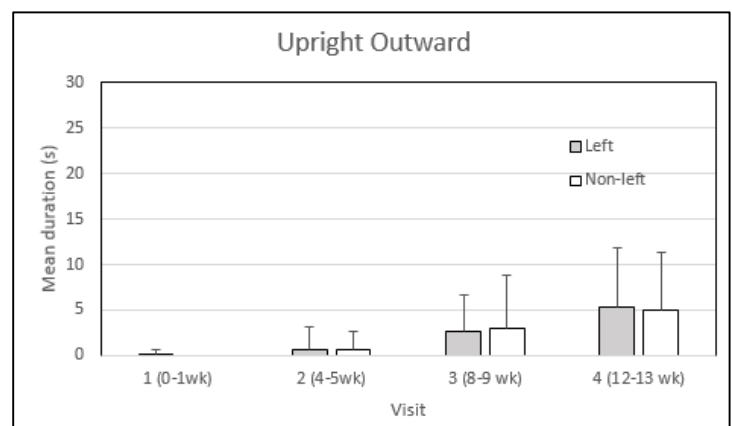
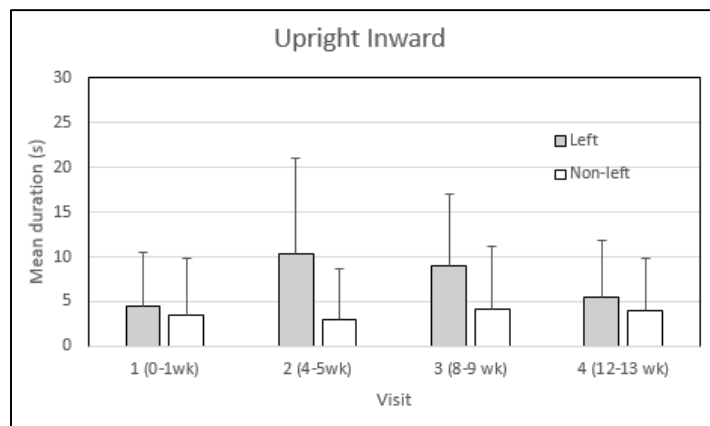
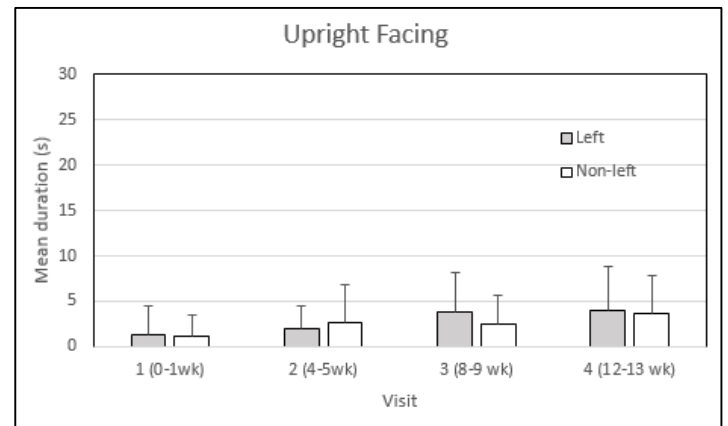
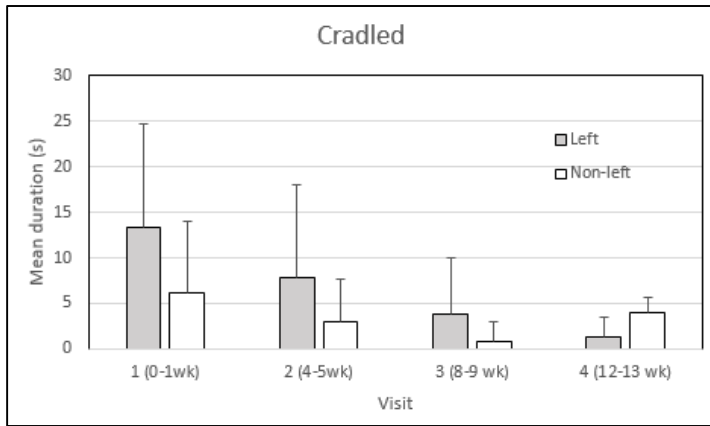


Figure 1. The mean duration of holding the infant at each side and site over twelve trials at each visit (maximum mean duration = 30s).